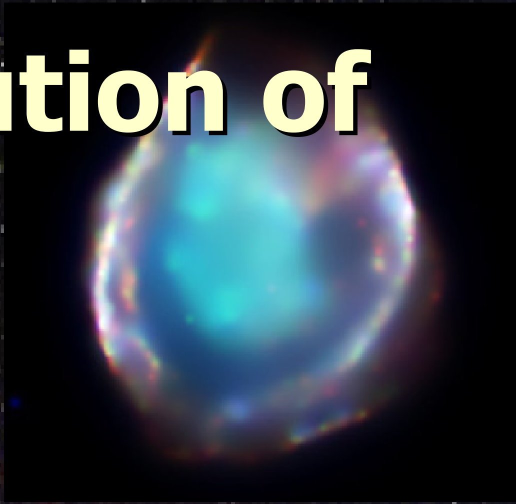


Production and Distribution of the Elements

John P. Hughes

Rutgers University

Con-X Panel Charge and Membership

Supernovae and their Remnants
Heavy metal/dust production
Shock Physics

Chair: Jack Hughes (Rutgers University)

Carlos Badenes (Princeton)
David Burrows (PSU)
Tracey Delaney (MIT)
Fiona Harrison (Caltech)
Martin Laming (NRL)
Julia Lee (Harvard)

Sangwook Park (PSU)
Dan Patnaude (SAO)
Dave Pooley (Wisconsin)
Stephen Reynolds (NCSU)
Pat Slane (SAO)
Alicia Soderberg (Princeton)

Key Topic I

Nucleosynthesis and Explosion Mechanisms in Supernovae through Con-X studies of Supernova Remnants

Core Collapse SNe

- ~ 3/4 of all SNe
- M(progenitor) > 8 solar masses
- Predominant producers of O, Ne, Mg
- Leave compact remnants
- Gaseous remnants highly structured and asymmetric
- Precise explosion mechanism unknown

Thermonuclear SNe

- ~ 1/4 of all SNe
- White dwarfs that grow to near the Chandrasehkar mass
- Predominant producers of Fe
- Gaseous remnants relatively symmetric
- Progenitor systems and precise explosion mechanism unknown

Key Topic I

Nucleosynthesis and Explosion Mechanisms in Supernovae through Con-X studies of Supernova Remnants

Why X-rays?

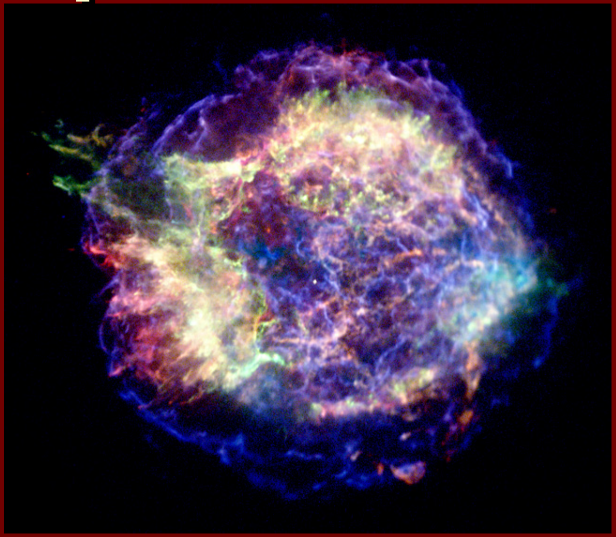
- Uniquely illuminate the composition and dynamics of the shocked ejecta and ambient medium – no other wave band offers as comprehensive a view
- SNRs offer a 3-D view of the entire ejecta – impossible to obtain on any individual SN, for which we sample a single line-of-sight

Why Con-X?

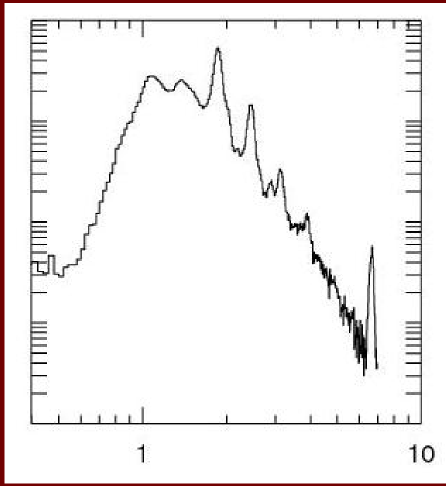
- Current CCD “spectroscopy” is more akin to BVRI imaging than true optical spectroscopy
- Temperature and ionization diagnostics based on line ratios
- Radial velocities and line broadening
- Access to SNRs in M31 and M33

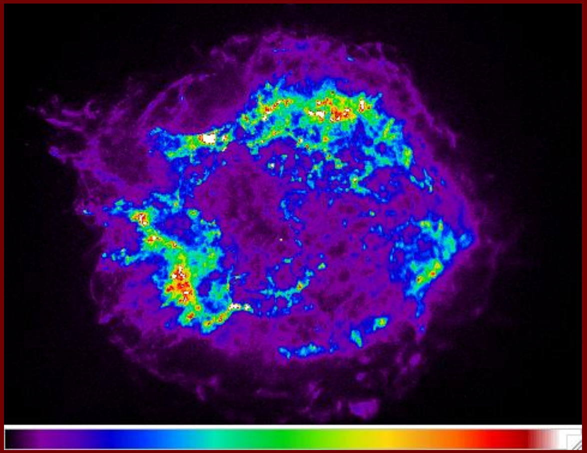
Target Core Collapse SNRs

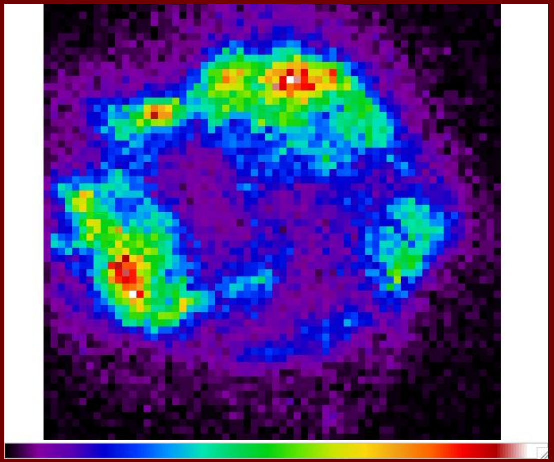
Cas A



- R ~ 2 arcmin
- Si, S, Fe-dominated ejecta
- Complex pattern of high velocity motions
- Clear signature of shock acceleration
- 15″ HPD not ideal: 5″ better match to knot sizes



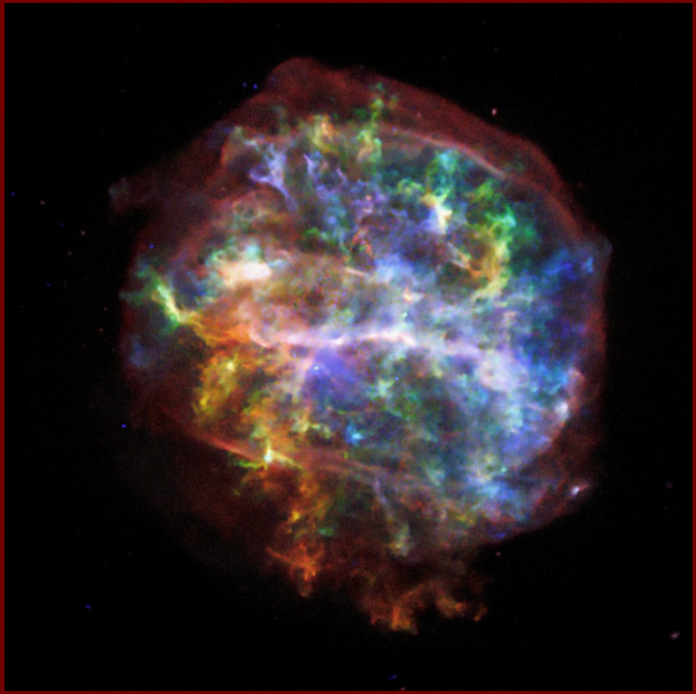


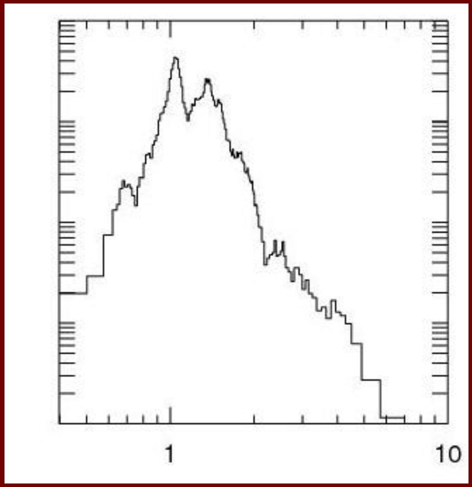


Target Core Collapse SNRs

G292.0+1.8

- R ~ 5 arcmin
- O, Ne, Mg-dominated ejecta
- Asymmetry in X-ray/optical emission from SE to NW
- Pulsar and PWN
- No sign of shock acceleration
- 15” HPD probably OK



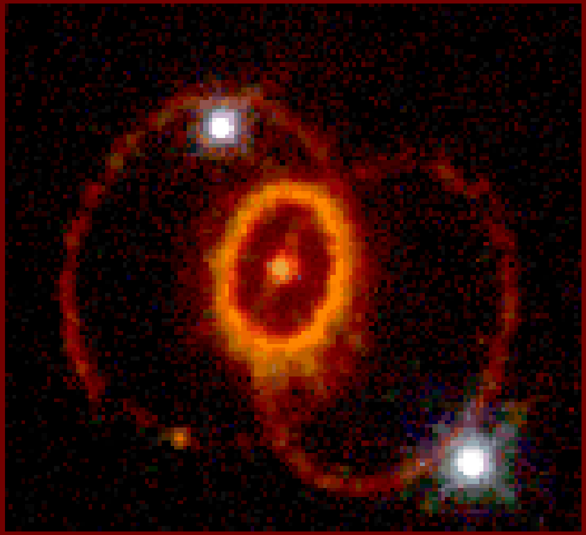


Target Core Collapse SNRs

Nearby Young SNRS:

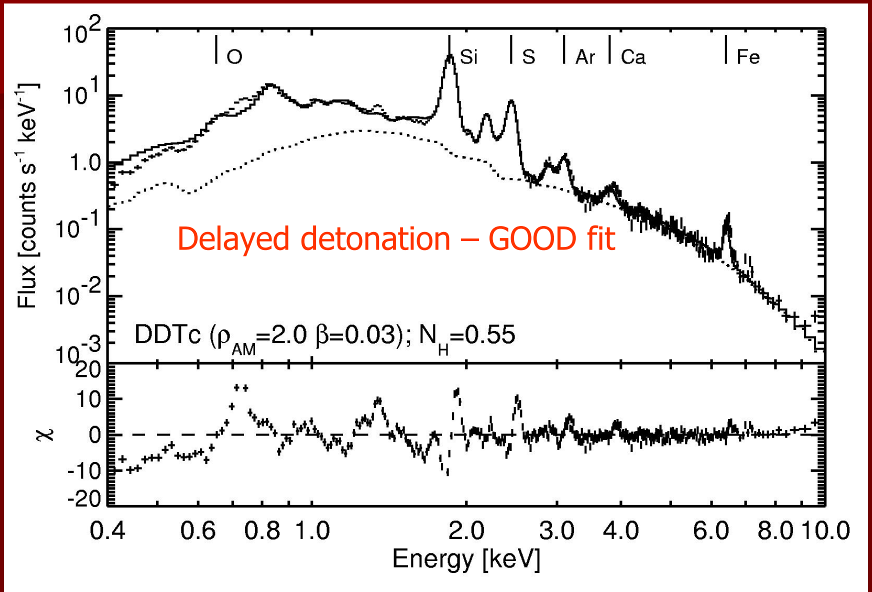
SN1987A SN1993J

- Study birth of the SNR and (possibly) pulsar
- Reveal the immediate circumstellar structure and chemical composition around the massive progenitor, and its late-stage stellar evolution history.



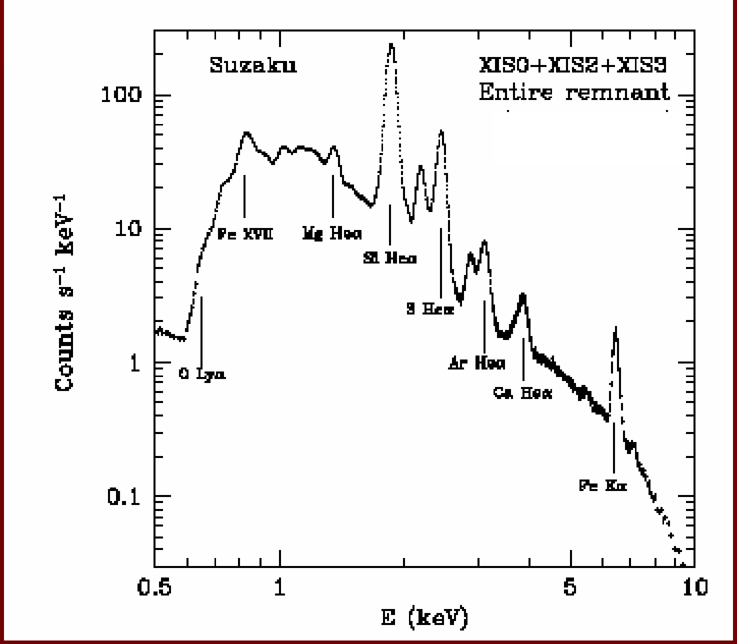
Tycho, a SN Ia Remnant

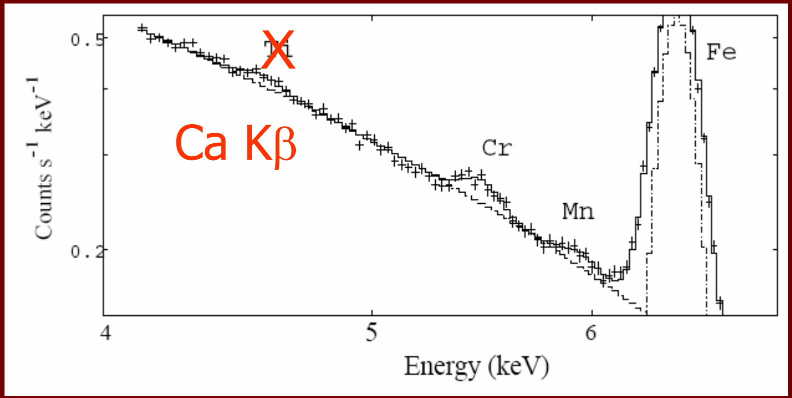
XMM-Newton (MOS)



Badenes et al 2006

Suzaku



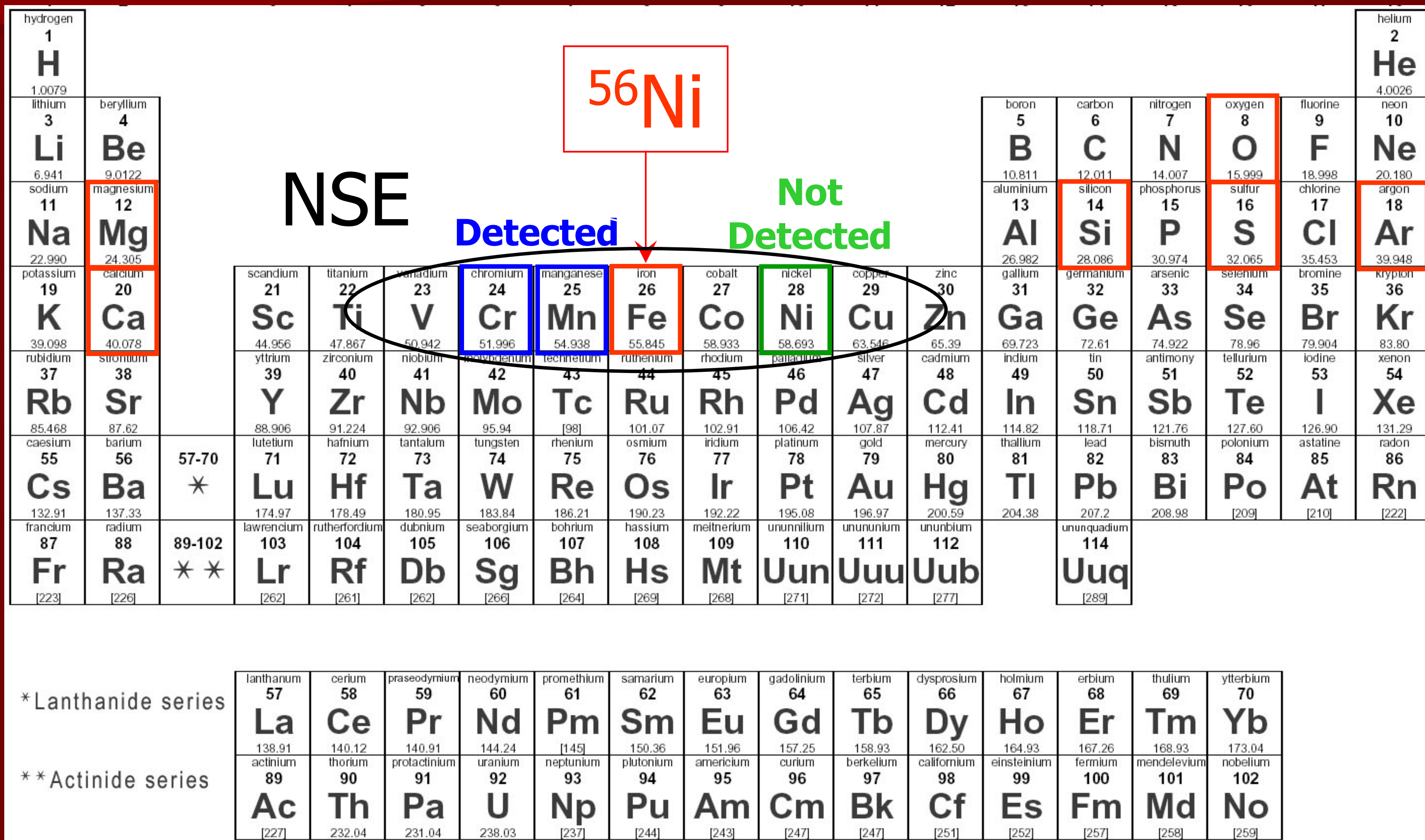


Tamagawa et al 2007

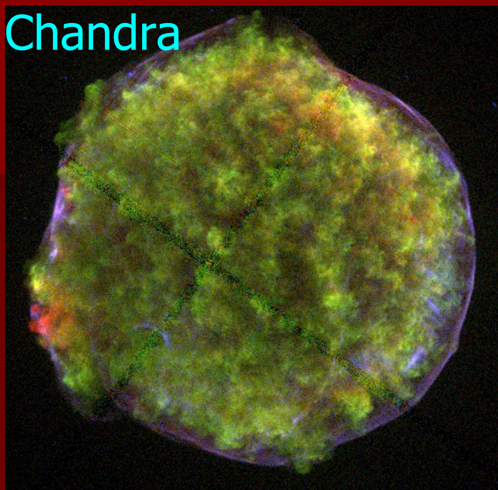
Hayato et al 2007

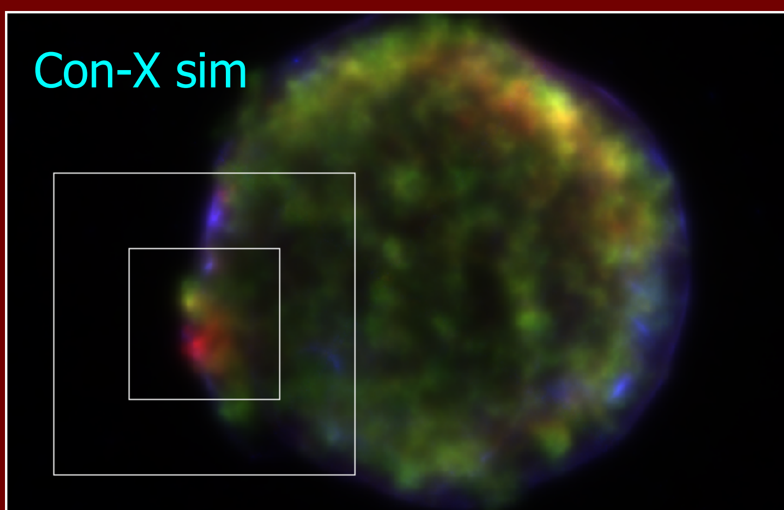
Fe-peak Elements in Tycho

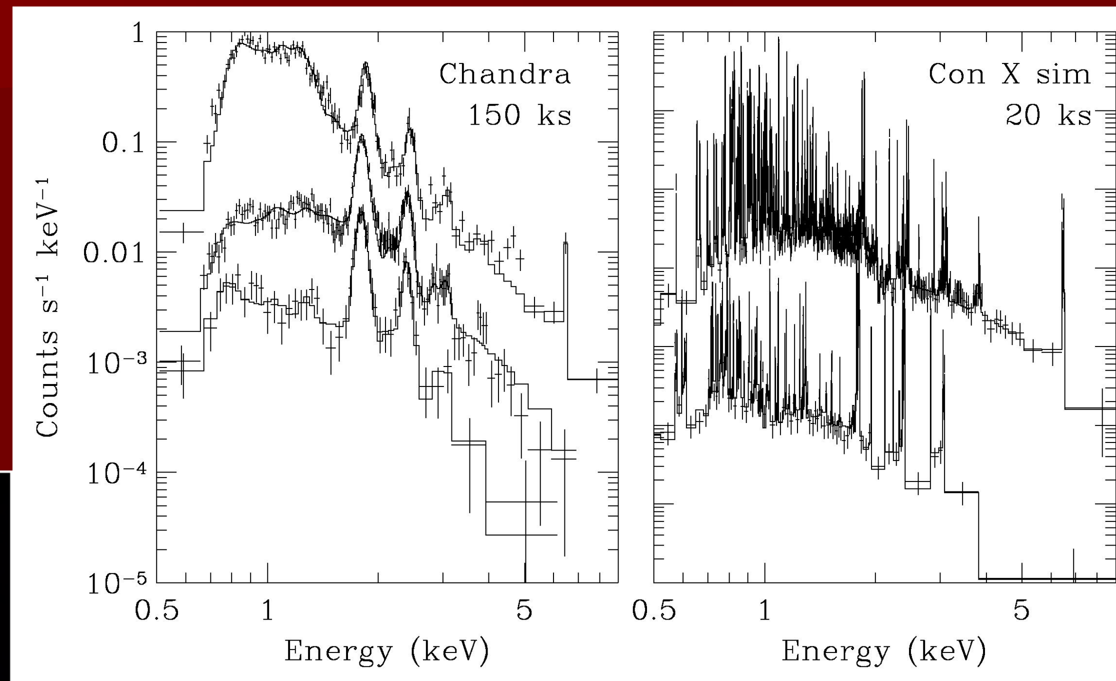
In SNe Ia nucleosynthesis is the explosion: C-O burns at high P and T to nuclear statistical equilibrium (NSE)



Con-X Simulations

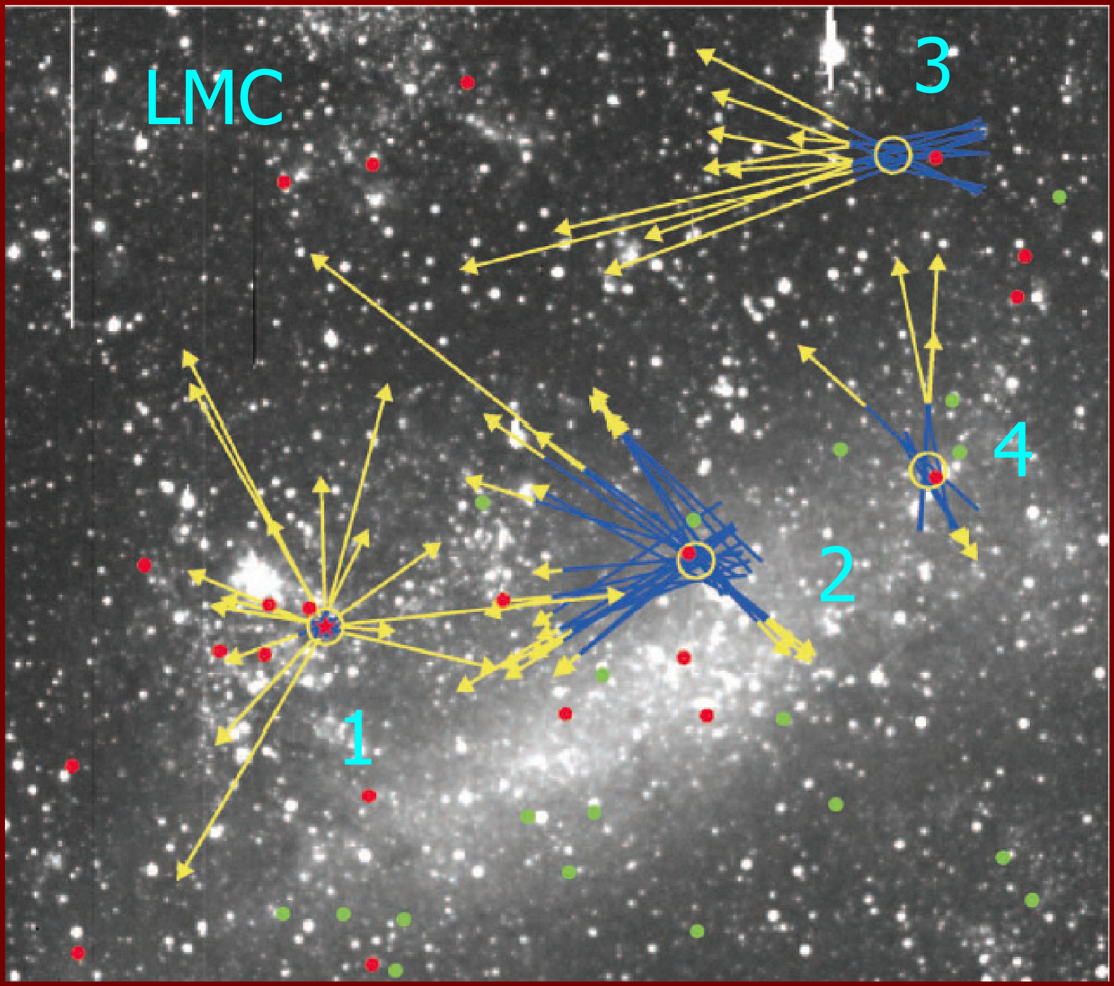






Well sampled spectra, on scale of Con-X PSF. Remnant size and characteristic knot size well matched to 15" HPD.

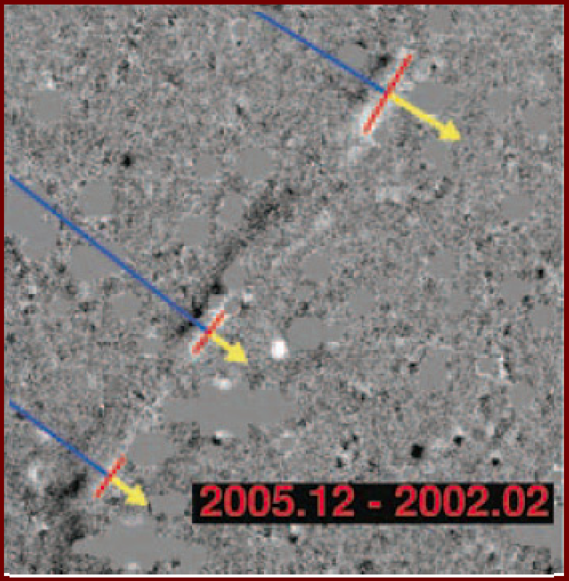
SNR 0509-67.5: A Spectroscopically Confirmed SN Ia



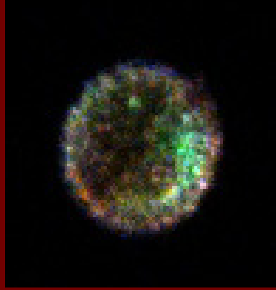
Rest et al 2005

Light Echoes from Old or Ancient LMC SNe

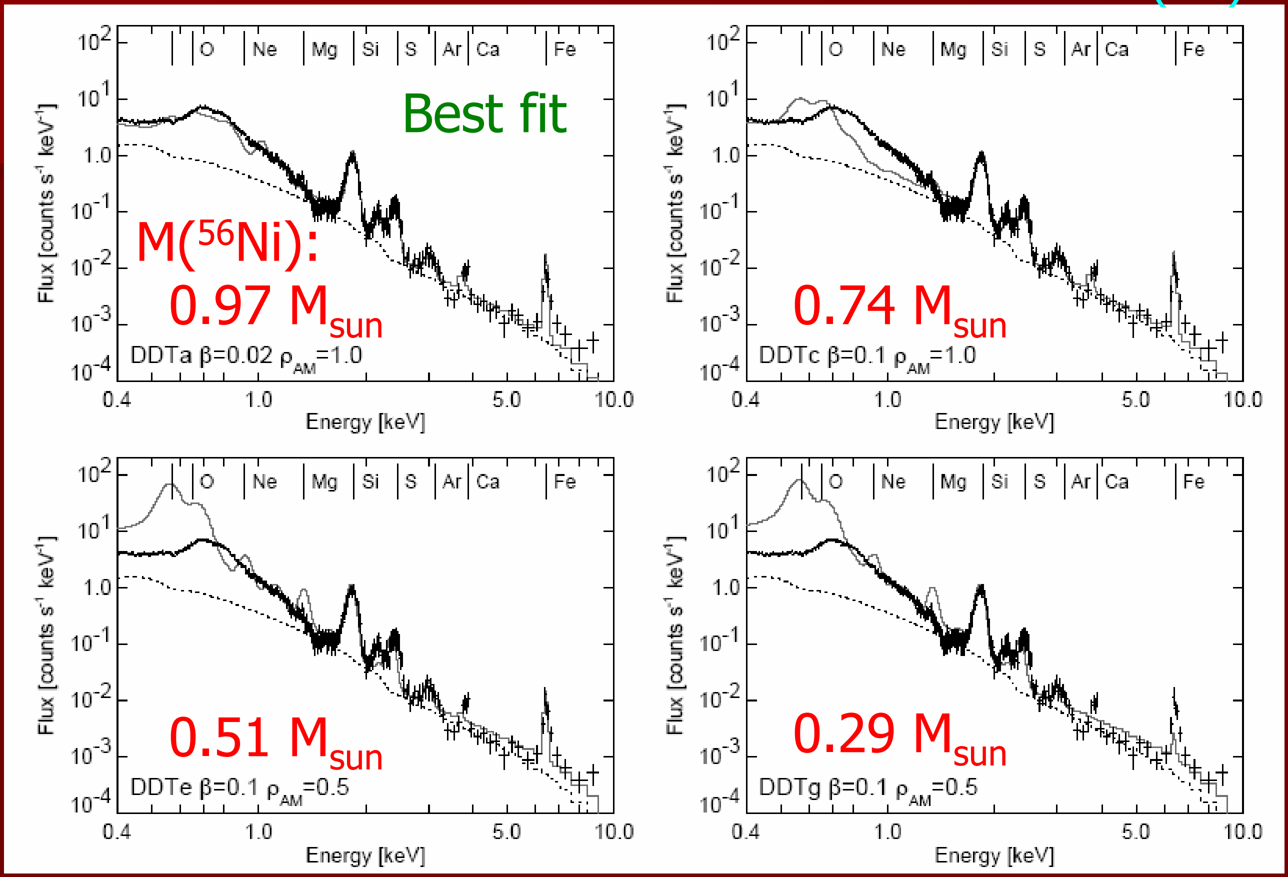
- 1) SN1987A 15 yrs
- 2) 0519-69.0 600 yrs
- 3) 0509-67.5 400 yrs
- 4) N103B 900 yrs



SNR 0509-67.5: X-ray Spectrum



XMM-Newton (PN)



Badenes, JPH, et al 2007, ApJ, in press

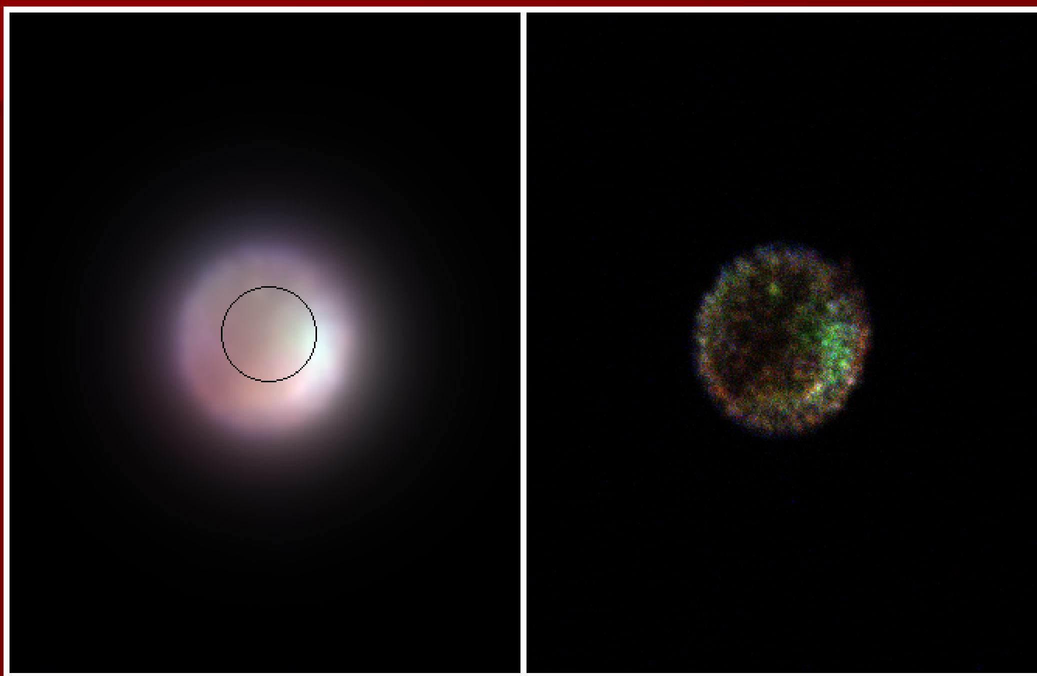
Constraints

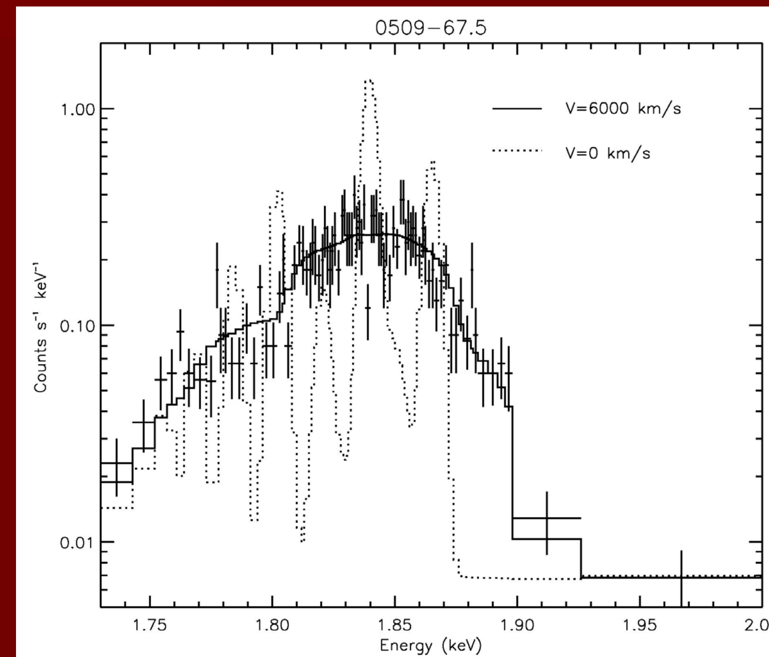
- Line Centroids
  - Si Kα
  - S Kα
  - Fe Kα
- Flux Ratios
  - O Kα/Si Kα
  - Fe L/Si Kα
  - Fe Kα/Si Kα

SNR 0509-67.5 is SN1991T-like

Recall 1 parameter variation of SNe Ia: Luminous-to-faint SNe correspond to high-to-low Ni mass

Con-X Simulations of SNR 0509-67.5





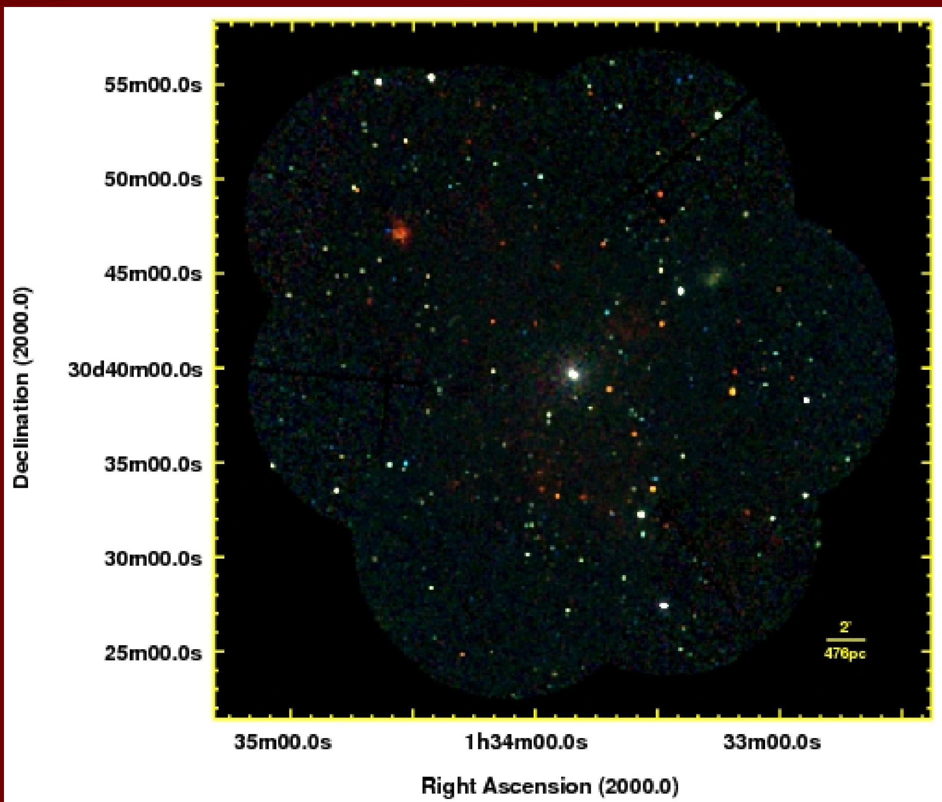
SNR 0509-67.5 6000 km/s

In resolved objects line broadening should vary with position; most relevant for SN1006 (shows some Si and S line broadening, Yamaguchi et al. 2007) and Tycho.

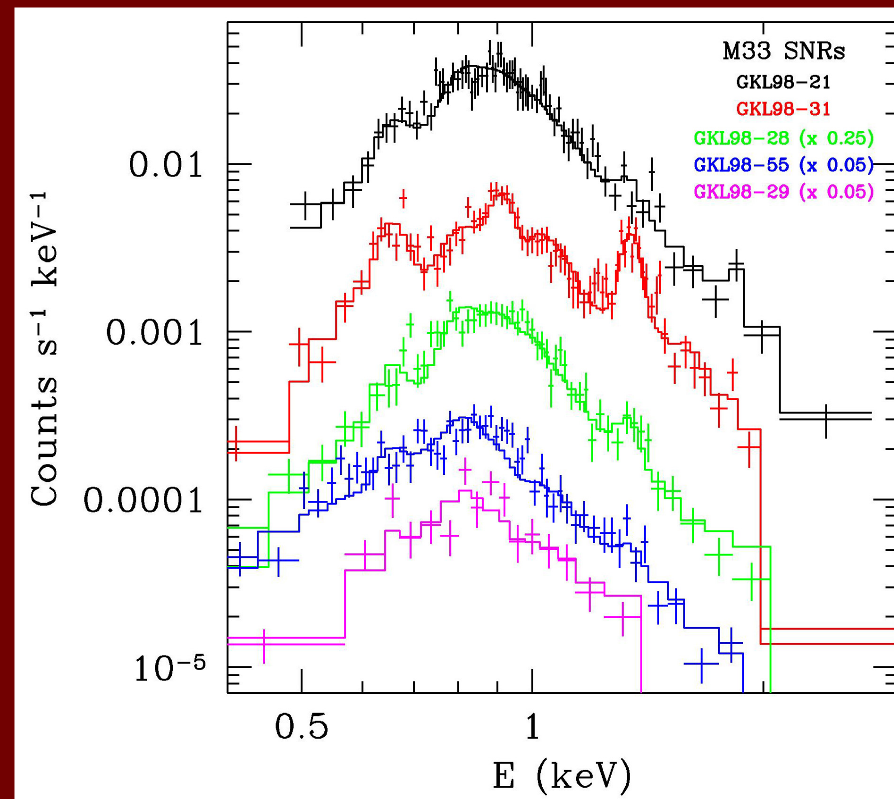
SNRs in M33

ChaSeM33

Chandra M33 VLP: mosaic of seven 200 ks exposures (Plucinsky et al)



Chandra X-ray color image

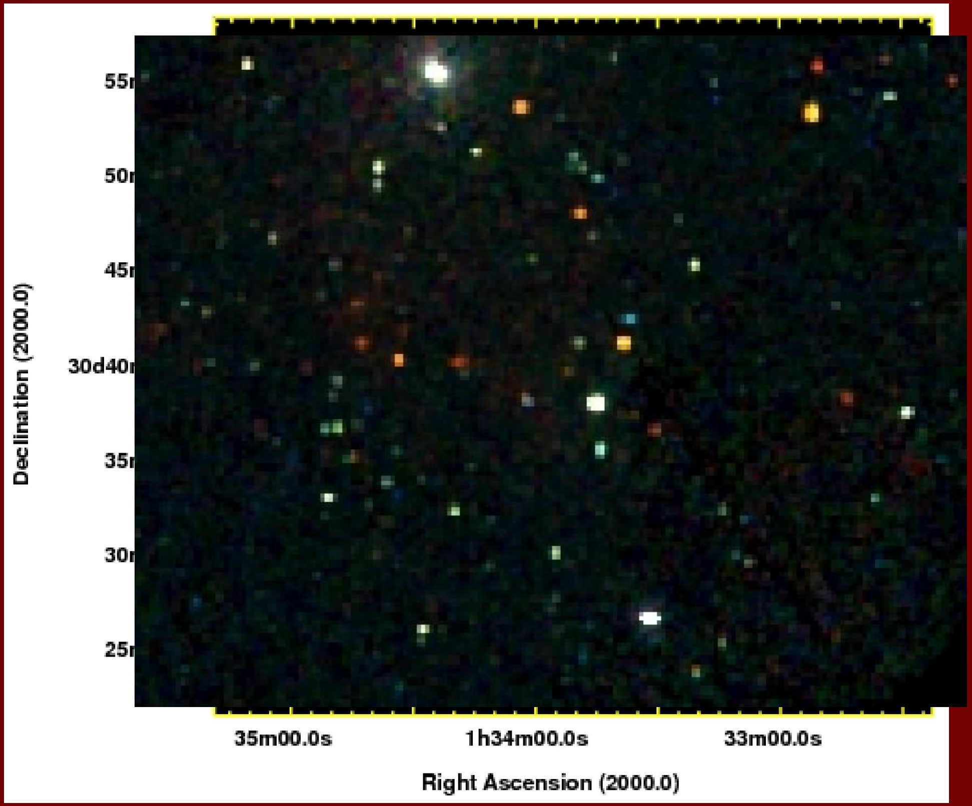


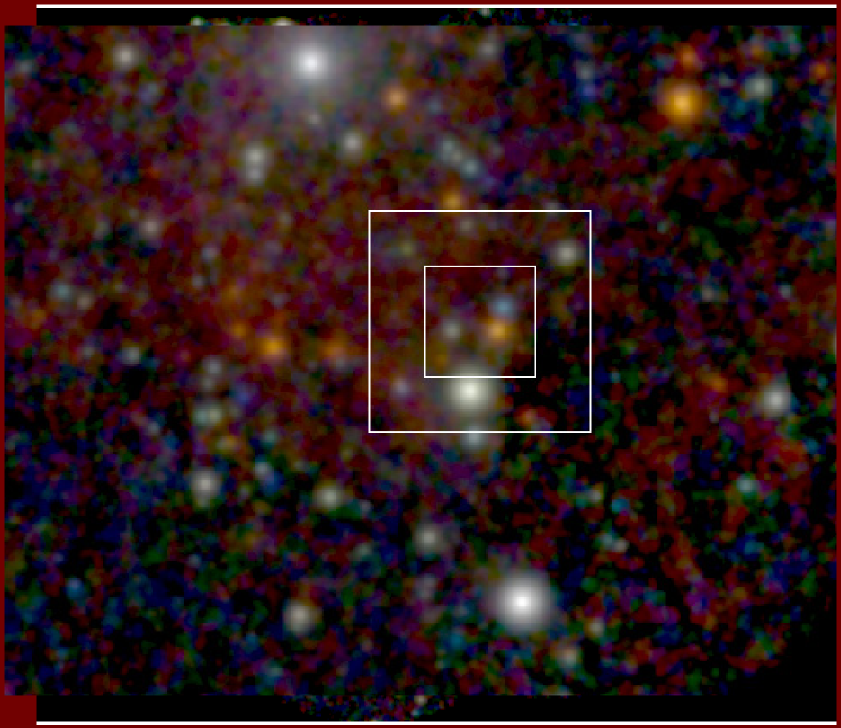
Chandra spectra of brightest SNRs in M33

SNRs in M33

ChaSeM33

Chandra M33 VLP: mosaic of seven 200 ks exposures (Plucinsky et al)





Chandra X-ray color image

Con-X imaging simulation (log scale display)

Key Topic II

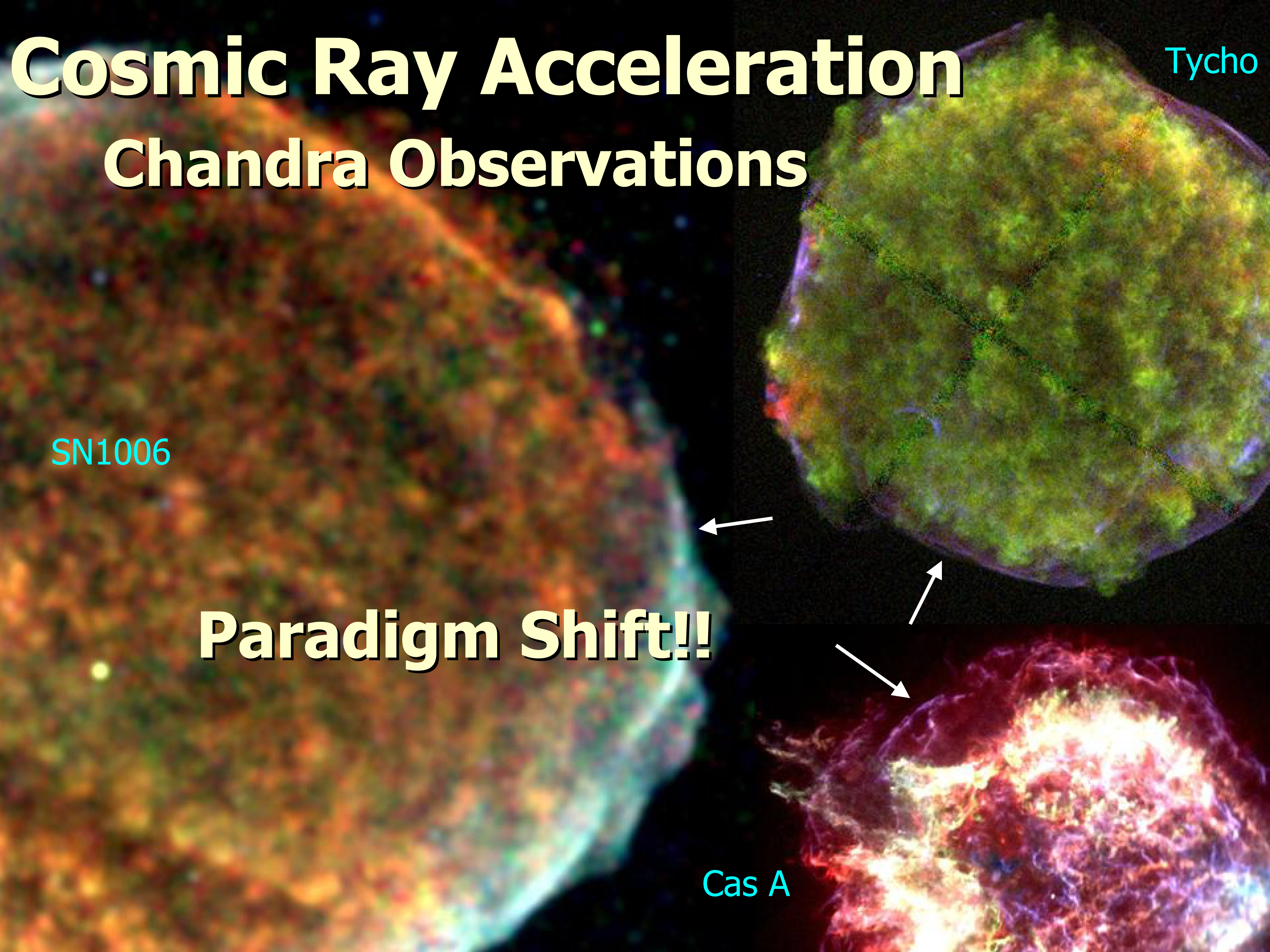
The Physics of Shocks

Basic Questions

- How do strong shocks in astrophysics accelerate cosmic rays, heat electrons, and amplify magnetic field?
- How do the thermal and nonthermal properties of strong shocks interact?

Cosmic Ray Acceleration

Chandra Observations



Paradigm Shift!!

Key Topic II

The Physics of Shocks

Why X-rays?

- Synchrotron X-ray emission is observed from electrons with energies up to 100 TeV. Spectrum steepens due to limitations on the acceleration process; detailed modeling gives information on particle diffusion and other properties.
- Thermal continua and ionization states of elements yield electron temperatures that are often far lower than the mean temperature inferred from independent determinations of shock speeds. Thermal analysis can give information on how energy is shared among ions, thermal electrons, accelerated particles and bulk motion.
- Thin rims of synchrotron X-rays may indicate the depletion of electrons by synchrotron losses on very short length scales, demanding large magnetic fields.
- Distance between forward shock and contact discontinuity far smaller than expected unless relativistic protons dominate the EoS in the shocked zone.

Key Topic II

The Physics of Shocks

Why Con-X?

- Calorimeter resolution will allow measurement of separate temperatures for electrons and for different ions, as well as Doppler widths and shifts.
  - Quantify the extent of electron heating
  - Constrain non-Maxwellian components of the electron distribution (the lowest-energy cosmic rays?)
  - Identify the fraction of shock energy going to accelerated particles.
  - Sensitive search for thermal emission from ambient medium in synchrotron dominated SNRS (e.g., RX J1713) – resolve leptonic (Inverse Compton) or hadronic (pion decay) origin of HESS TeV γ-ray emission
- How common is synchrotron X-ray emission in shell SNRs? How common are brightness fluctuations of synchrotron components?

Other Topics

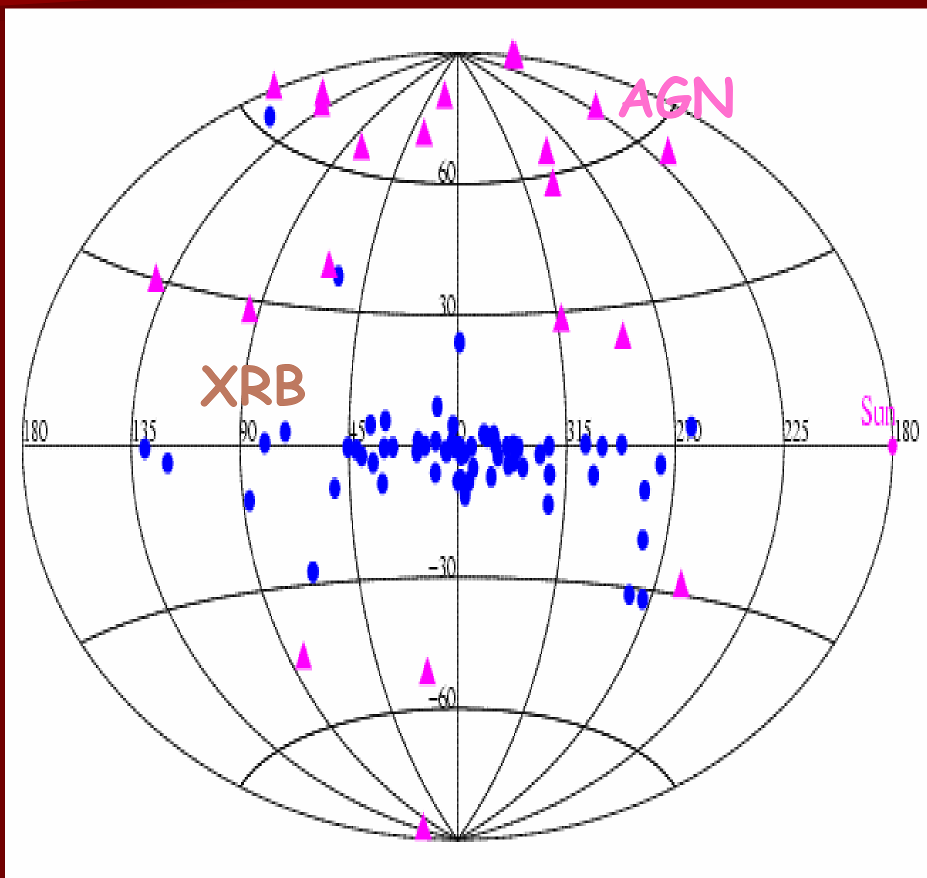
Pulsar Wind Nebulae

Basic Questions

- How do pulsar winds interact with their environment?
- Where is the ejecta surrounding "naked" PWNe such as the Crab?
- What is the maximum energy of particles in pulsar wind nebulae and what is the particle composition of the wind?

Distribution, composition, and state of the dust and gas in the interstellar medium

Mapping the ISM
("for free")
Gas, Molecules & Dust

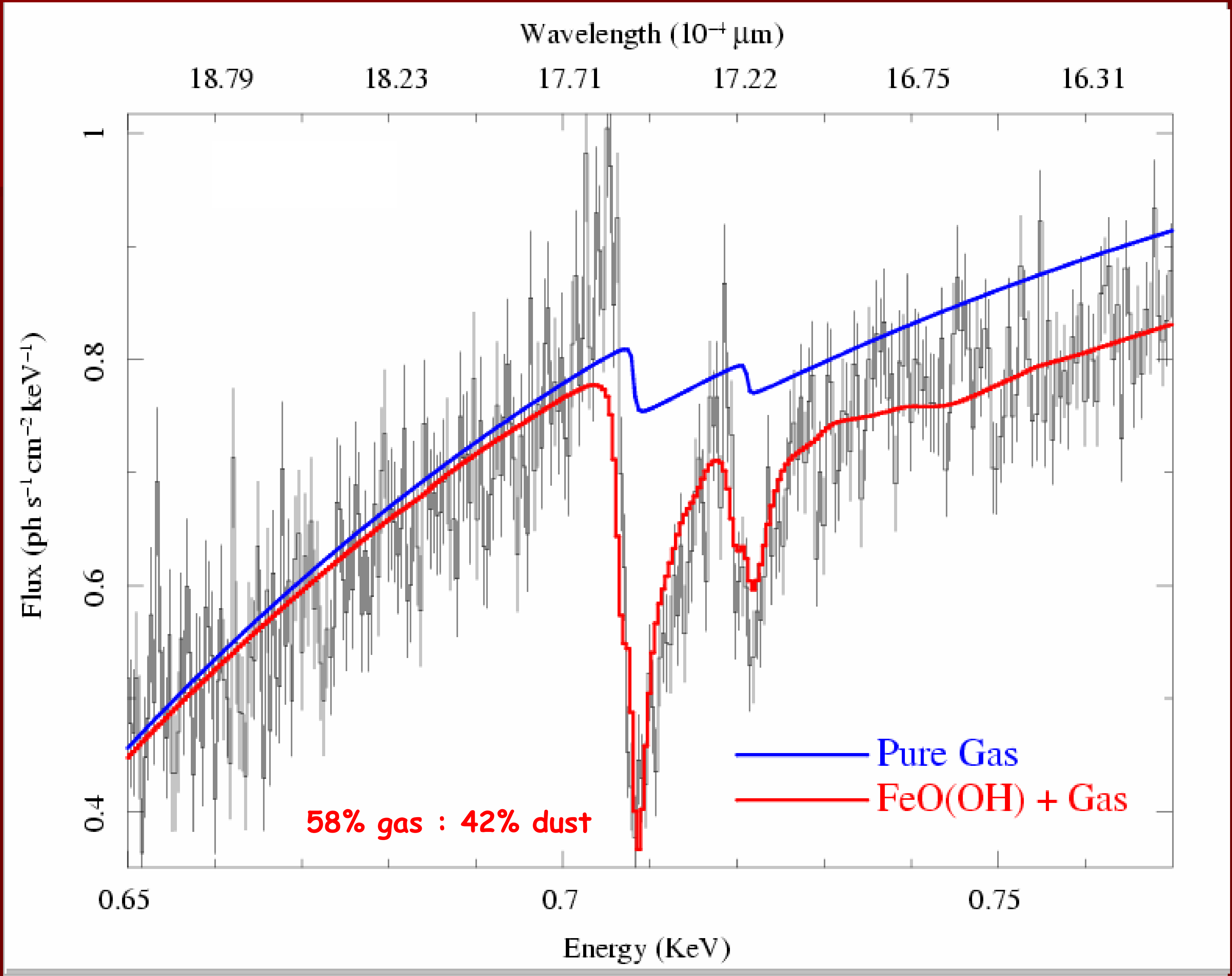


- Spectral studies of XRBs/AGNs through ISM/IGM material will imprint signatures in XRBs & AGN spectra
- Studies along multiple LOS will map ISM distribution to determine origin and distribution: halo/disk -> implications for testing 3 phase ISM
- XAFS studies will determine molecular and/or dust composition in different environments - cold diffuse ISM and/or near BH/NS environments
- Dust scattering halo studies will determine distribution of dust
- Applications to all areas of astrophysics: planetary science, star formation, Cosmology
- Symbiotic with Chemistry and Atomic-Molecular-Solid State Physics

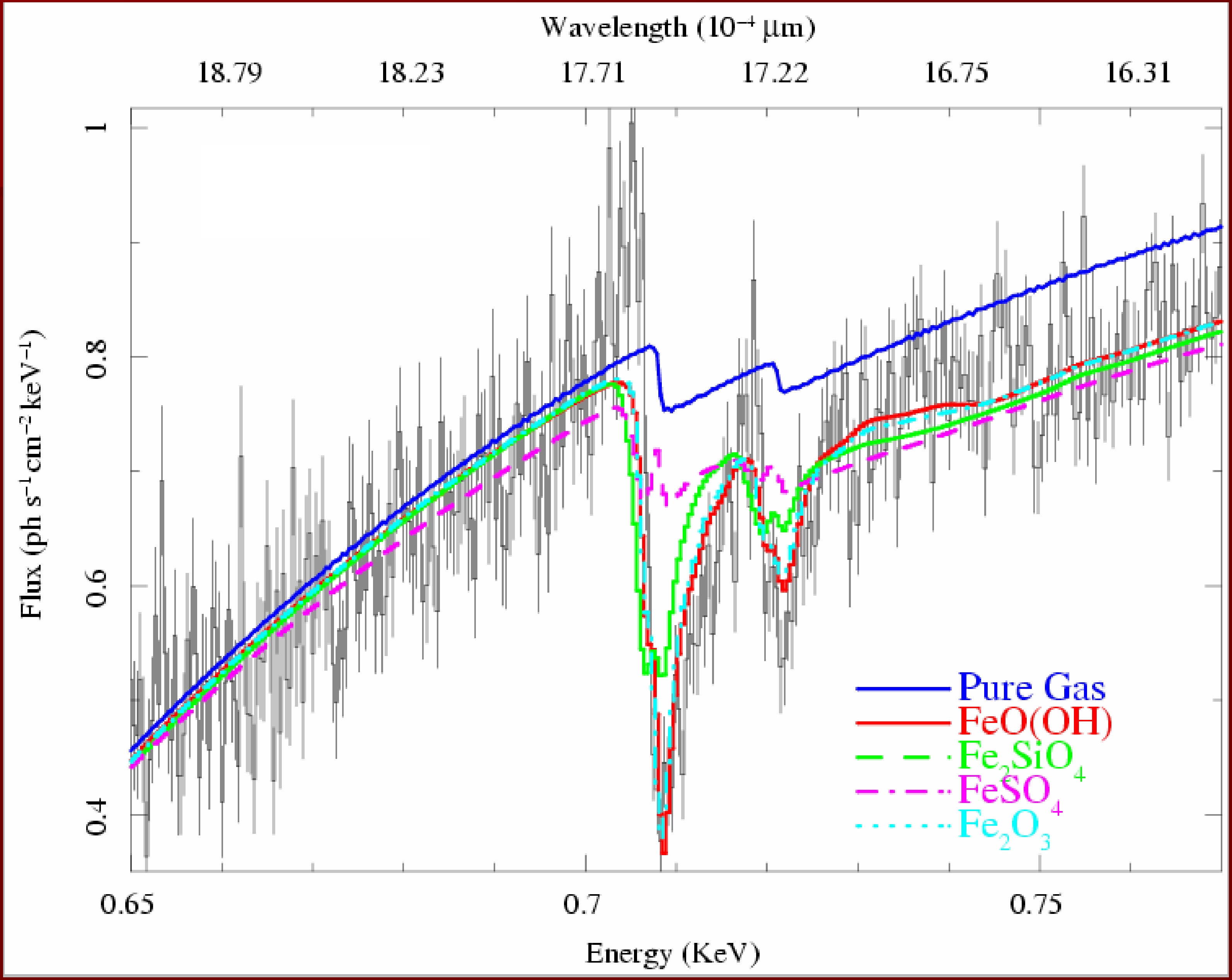
Multiwavelength studies of dust

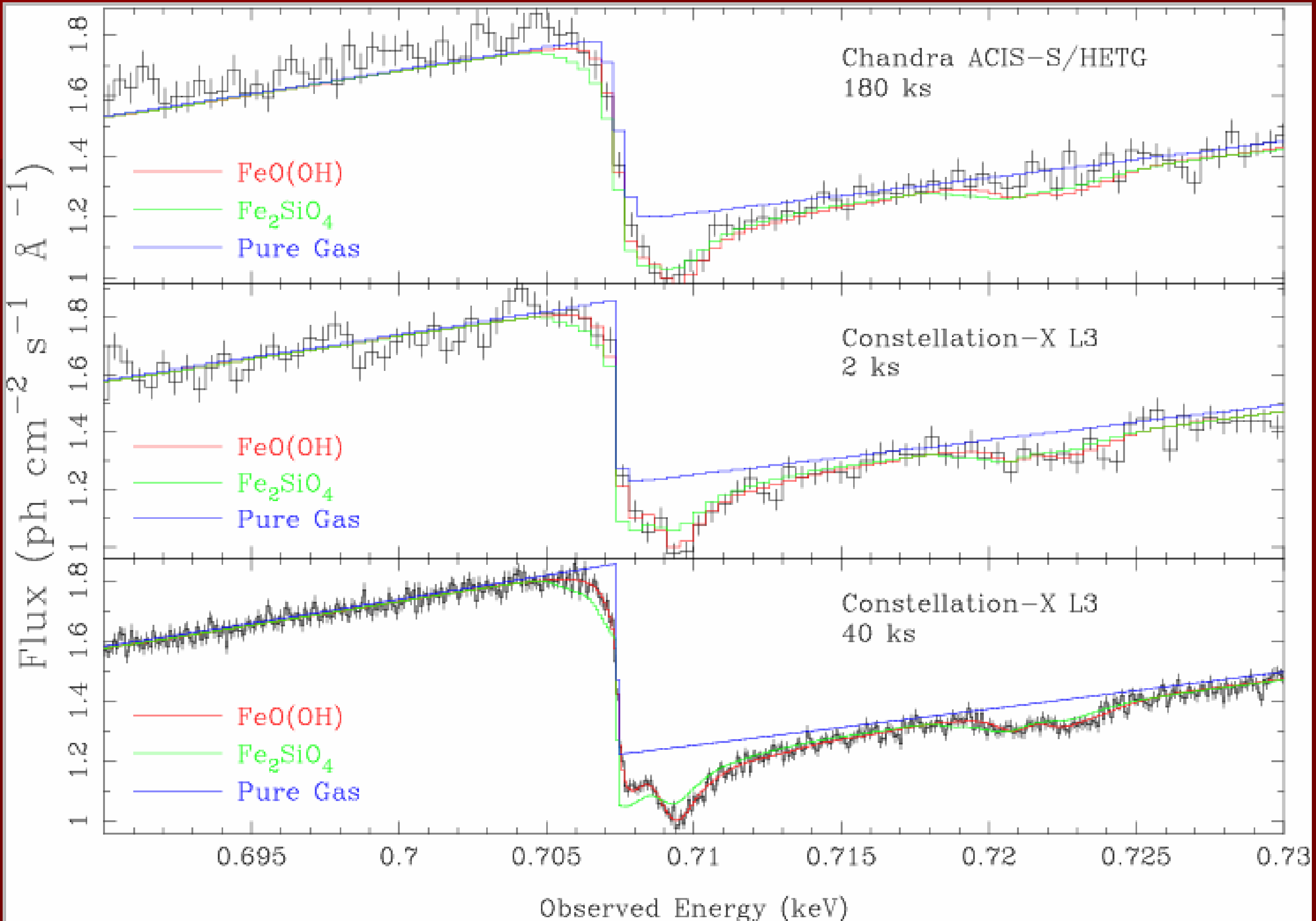
- X-rays : unique probe of <u>solid state</u> nature of molecule;   sensitive to ALL atoms in both gas and solid phase
- IR : can directly probe vibrational modes, but limited to PAHs, graphites and certain silicates (~2.5-25 μm region). Cannot easily speciate the grain composition
- UV : dust inferred from the depletion factor (amount expected : measured)
- Optical : dust inferred from redding/extinction, polarization
- Radio : probe gas phase; 21cm, CO, etc.

Iron Compounds



Iron Compounds




Chandra ACIS-S/HETG
180 ks
FeO(OH)
Fe_2SiO_4
Pure Gas
Constellation-X L3
2 ks
FeO(OH)
Fe_2SiO_4
Pure Gas
Constellation-X L3
40 ks
FeO(OH)
Fe_2SiO_4
Pure Gas
Flux (ph cm^{-2} s^{-1} Å^{-1})
Observed Energy (keV)
0.695
0.7
0.705
0.71
0.715
0.72
0.725
0.73
1
1.2
1.4
1.6
1.8